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QUALITY AND NUTRITIVE VALUE OF DATES AS INFLUENCED BY THEIR CHEMICAL COMPOSITION

C. E. Vandercook, S. Hasegawa, and V. P. Maier

*Research Chemist, Research Chemist, Research Chemist and Research Leader,
respectively, Fruit and Vegetable Chemistry Laboratory,
U. S. Department of Agriculture, SEA, AR, Pasadena, California 91106.*

ABSTRACT

The quality and nutritive value of dates as influenced by their chemical composition are discussed under the headings of carbohydrates, protein and amino acids, lipids, organic acids, vitamins, minerals, polyphenolics, enzymes, and miscellaneous compounds. This well-documented paper summarizes the results of original and previously reported research.

Date Growers' Inst. Rep. 54:3

Dates are an important crop in the desert regions of the world, yet they have been the subject of relatively few chemical studies. Over the years, a number of reviews and technical bulletins on date production have included brief sections on chemical composition (12, 27, 40, 45, 48, 55).

A recent review by Rygg (48) briefly covers much of the chemical compositional work through 1970 and gives an excellent general review of the date industry in the United States. Since 1970 there has been a surge of interest in the composition of dates at a more fundamental level. The present review deals with the chemical composition of dates as related to the nutritive value and sensory acceptance with a major emphasis on the research published during the last 20 years.

CARBOHYDRATES

SUGARS

Dates and other dried fruits (Table 1) are mostly composed of carbohydrates, with small amounts of other nutrients. With the exception of the substantial amounts of vitamin A in apricots and prunes, the composition of dates is quite similar to that of other dried fruits.

Sugars are the most prevalent compounds in dates and have been widely

studied. Most reports, however, have been limited to total and invert sugars, their ratios, and changes with maturity. Nutritionally, the invert sugars are the most important constituents, for they provide readily available energy calories. The sweetness contributed by the sugars probably is the chief reason for the popularity of dates.

The ratio between sucrose and reducing sugars depends on the variety and changes as the fruit matures. In the date literature, reducing sugars commonly have been thought of as an equimolar mixture of glucose and fructose arising from the inversion (hydrolysis) of sucrose. This is only approximately correct, for Coggins *et al.* (7) found a fructose glucose ratio of 1.28 for California 'Deglet Noor' dates.

Hussein *et al.* (23) characterized several varieties of ripe Saudi Arabian dates into three generally accepted categories (Table 2). "Soft" dates with high moisture contain almost no sucrose. "Semi-dry" type dates (which would include Deglet Noor) have a moisture range of 20-30% and a higher sucrose level. "Dry" dates, with moisture levels less than 20%, contain approximately equal quantities of sucrose and reducing sugars.

Within a given date variety sucrose and reducing sugars are related to quality and texture (8). Although the total sugars (as percentage of dry weight) were essentially the same for all grades, the better grades have more grams of total sugars per date than do lesser grades. This higher amount of sugar in better-grade dates is significant in terms of timing the harvest, all other factors being equal, for early harvest results in greater numbers of immature dates, with a lower sugar content, than does late harvest.

The changes in sugars during fruit maturation have been known in general terms for a long time. Vinson (55) report-

ed that total sugars and sucrose increased with ripening and noted the rapid accumulation of total sugars and the inversion of sucrose at the later stages of development. As a further example, Ragab *et al.* (41) studied these changes in six varieties of soft and semi-dry Egyptian dates. In the early green stage, reducing sugars typically made up about 30-40% of the dry weight and sucrose nearly zero. As the color started to turn (khalal stage), reducing sugars reached a maximum of around 50-60% and sucrose rapidly increased in concentration. At the end of the turning phase, the concentration of reducing sugars began to drop while the total sugar concentration increased slightly to about 80-90%. At the fully colored stage (rutab), the concentration of reducing sugars and sucrose were both around 35-40%. During curing of the soft varieties, sucrose underwent an essentially complete hydrolysis to reducing sugars.

CRUDE FIBER

Crude fiber in dates is roughly 2-4% of the dry weight. This crude fiber is commonly thought of as the insoluble, non-nutritive or undigestible portion of a food and includes pectins, lignins, hemicellulose, and cellulose.

The pectins are thought to have a significant effect on date texture by means of their gel formation during the commercial curing process.

Coggins *et al.* (9) examined the inner and outer mesocarp of premium quality and commercially acceptable, but low-quality, dates and found higher levels of pectins in the inner than in the outer mesocarp (Table 3).

The lignin and cellulose portions of the crude fiber in Deglet Noor dates were investigated in detail by Coggins *et al.* (9) (Table 3), and they found no significant differences between the Natural and No. 1

Dry grades. Ejlali *et al.* (13), who studied the cellulose in several varieties of Iranian dates, found that 'Mezaphatie,' 'Shahani,' 'Kabkabe,' and 'Sayer' dates contained 5.8, 4.15, 6.48, and 4.43 g/100 g, respectively.

PROTEIN AND AMINO ACIDS

Dates, although not a major source of protein, contain a small but important amount of protein. The food composition tables report protein as total N x 6.25 which includes amino acids and other nitrogen-containing compounds in addition to protein. Protein levels in dates range from about 1.5-2.0% by weight, and this protein has been reported to be of a high nutritive quality when compared with the standard egg protein (2).

Early identification of the date amino acids was by paper chromatography (16, 17, 43). Recently, Al-Rawi *et al.* (2), Sternkopf and Amin (53), and Auda *et al.* (4) studied Iranian dates with an amino acid analyzer (Table 4). A high degree of similarity was noted in composition between varieties and, in 'Khdrawy' dates, over several seasons. This might be expected, however, for most of the amino acids are in the form of protein.

LIPIDS

The fat content of dates measured as ether-soluble extracts makes a trivial contribution to the total caloric value. Until recently, there has been little interest in date lipids. Hilgeman and Smith (22) determined the crude fat content of several date varieties and found that it ranged from 2.52% for 'Hayany' to 7.42% for 'Maktoom.'

Date pits are not normally considered edible for man, although they have been mixed with cattle feed and even ground up and blended with flour for human consumption. Bennett *et al.* (5) investigated the sterols of date seeds and pollen and found cholesterol and estrone in both. Estrone was later identified in pollen of the 'Samani' variety dates in Egypt (3). The fatty acid composition of date pit oil is given in Table 5.

Kikuchi and Miki (24) studied the lipids in Iraqi dates (no variety reported) and identified, by gas-liquid chromatography, propionic, isobutyric, *n*-butyric, isovaleric, *n*-valeric, isocaproic, *n*-caproic, *n*-heptanoic, caprylic, pelargonic, and cap-

ric acids. The long-chain fatty acids consisted of lauric, myristic, pentadecanoic, palmitic, margaric stearic, oleic (or possibly elaidic and linoleic), and linolenic acids. Palmitic acid was the major acid followed by capric and caprylic acids. Later, in a comprehensive study on the sterols in dates (25), they found cholesterol, campesterol, stigmasterol, *b*-sitosterol, and isofucosterol.

ORGANIC ACIDS

Although organic acids contribute little to the nutritive value of dates, they do affect the flavor and quality. Rygg (46) noted that pH values were proportional to quality in Deglet Noor dates. For example, the pH ranges for the grades Fancy and No. 2 Dry were 6.0-6.9 and 4.9-5.7 respectively. The acidity also differed with variety. Ejlali *et al.* (13) reported acidities for Iranian dates of 2.53, 3.80, 4.20, and 4.43 meq/100 g dates for Mezaphatie, Kabkabe, Shahani, and Sayer varieties, respectively.

Rygg (47) observed that Deglet Noor dates with a low pH value had significantly more sulfur than dates with high pH. Although the sulfur dust used to control mites was suspected as the cause of the problem, experimental studies showed no significant differences between sulfured and unsulfured dates as far as composition or pH were concerned. Generally, pH increases and titratable acidity drops as fruit matures. For example, in a recent study of Shahani dates grown in Iran, Rouhani and Bassiri (44) reported that the pH increased from 5.13 to 7.00 and the titratable acidity dropped from 7.7 to 1.4 meq/100 g dry weight.

We were unable to locate any reference to the identification of the organic acids in ripe dates. These acids are probably qualitatively similar to the acids (Table 6) found in green Deglet Noor dates by Maier and Huber (unpublished data).

VITAMINS

In the 1930s and 1940s several groups of researchers studied the vitamins of dates (11, 15, 26, 28, 37, 49, 51). The representative values listed in Table 1 indicate that dates are not an exceptionally rich source of vitamins. However, if the vitamin content is expressed in proportion to calories, dates contribute roughly their recommended share of sev-

eral important vitamins. For thiamine, riboflavin, and nicotinic acid, the recommended levels (39) are 0.4, 0.6, and 6.6 mg/1000 cal, and dates contain 0.32, 0.35, and 8.0 mg/1000 cal, respectively (Table 1).

Maier and Schiller (33) isolated a crystalline mesoinositol from green dates. Because the procedure was not quantitative, the 0.04% found in the dates can only be considered a minimum. Ripe dates were not tested. Inositol hexaphosphate was detected in date seeds at the level of 23 mg/100 g (10).

MINERALS

Potassium is by far the most abundant mineral element in dates (Table 1). Phosphorus and calcium are next, then iron. Other elements reported (18) include sodium, magnesium, copper, manganese, and chlorine. The mineral composition for two date varieties is listed in Table 7. The high potassium and low sodium levels in dates can be quite important to persons on low sodium diets. The iron content calculated on a per-calorie basis (1.1 mg/100 cal) contributes significantly to the daily requirements.

POLYPHENOLICS

The polyphenolic constituents of dates (Table 8) are important to both the flavor and color of the fruit.

TANNINS

Tannins, the most complex polyphenols in dates, have been recognized for many years (55), undoubtedly because tannins occur in substantial amounts in green fruits, where their astringency makes the fruit unpalatable. Over the years several workers have reported a decrease in the soluble tannin content as the fruit matured (14, 41, 54).

Maier and Metzler (30, 31) characterized both water-soluble and water-insoluble condensed tannins in Deglet Noor dates. These procyanidin tannins increased in the fruit during the green and red stages of maturity. The soluble procyanidin tannins were the predominant extractable polyphenolic constituents of immature Deglet Noor dates, but were not detected in the ripe or stored stages. The insoluble tannins were highest in the ripe stage and then decreased during storage. The increase in insoluble tannins of the ripe stage is believed to be the result

of a conversion of soluble to insoluble tannins during maturation. The decrease in insoluble tannins during storage suggests that they are involved in deteriorative systems, such as browning. Tests with date phenolase showed that neither the soluble nor insoluble tannins were darkened through the action of this enzyme (30).

FLAVANS

The flavans are simple polyphenols present in lesser amounts than the soluble tannins, and as a group they decrease gradually during maturation and storage (30). The flavans produced a brownish color when treated with date phenolase, establishing them as enzymic browning substrates. The presence of the flavans in the green and red stages and their absence from the ripe and stored stages also suggests their involvement in browning.

Maier and Metzler (unpublished data) isolated (+) - catechin and tentatively (-) - epicatechin. Catechin was present in green- and red- stage fruit, whereas epicatechin was present only in green-stage fruit. The early loss of epicatechin correlates with the high rate at which date phenolase catalyzes the oxidation of these compounds.

CAFFEYOYLSHIKIMIC ACIDS

The major ethyl acetate-soluble polyphenols in green Deglet Noor dates are the dactylifric acids, the three position isomers of monocaffeoylshikimic acid (29, 32). The dactylifric acids, which gave brown products when treated with date phenolase, occurred in green-, red-, and ripe-stage dates, but not in stored dates.

FLAVONES AND FLAVONOLS

Turrell *et al.* (54) reported the existence of flavones (based on color tests) in the epiderm and hypoderm tissues of kimri (green stage) and khalal-stage date fruits. Maier and Metzler (unpublished data) isolated quercetin-3-glucoside and tentatively identified isorhamnetin-3-glucoside from immature Deglet Noor dates. These flavonol glycosides, which were present at all stages, were shown by direct tests not to be browning substrates for date phenolase (31).

ENZYMES

Investigators studying the enzymes of dates have been concerned mainly with those related to the quality factors of texture and color.

INVERTASE (B-FRUCTOFURANOSIDASE E. C. 3.2.1.26)

Invertase, which has been known to be in dates for a long time, is perhaps the most important enzyme that influences the quality of dates. Hasegawa and Smolensky (20) showed that invertase activity was higher in Natural and Waxy dates than in No. 1 and No. 2 Dry dates. They also estimated that Deglet Noor fruit contained about 12.5 units of invertase per fruit as the maximal level. Invertase developed in both its soluble and insoluble forms although at different rates. In immature fruit, only the insoluble form of the enzyme has substantial activity (5 units/fruit). The insoluble form of the enzyme was not a simple protein-tannin complex (20) and, it appeared to be bound in such a manner that the enzyme was accessible to the substrate to carry out its catalytic function. This suggestion was supported later by Sakri *et al.* (50). The insoluble invertase appeared to be converted to the soluble form as maturity progressed. Soluble invertase, virtually absent at the green stage, increased sharply as the fruit matured from the green to the early red stage, reached a maximum (10 units/fruit) at the late red stage, and then decreased slightly as maturity progressed. A similar trend was observed in the 'Zahidi' and Sayer varieties (50).

PECTIC ENZYMES

Both polygalacturonase (E.C. 3.2.1.15) (19) and pectinesterase (E.C. 3.1.1.11) (pectin methyl esterase) (1,9) are present in dates. Softening of fruit during ripening is related to alterations in the pectic substances through the action of pectic enzymes (19).

Change in polygalacturonase activity in Deglet Noor dates was a function of maturity (19). Activity was virtually absent at the green stage, remained low until the fruit reached the late red stage, then rose sharply, and reached its maximal level at the stage when individual fruits were 50% soft. Polygalacturonase activity was about one-third higher in soft (Natural and Waxy) dates than in the relatively tough (No. 1 and No. 2 Dry) dates (19).

Al-Jasim and Al-Delaimy (1) followed changes in the activity of pectinesterase during maturation and ripening of four varieties of Iraqi dates. Unlike cellulase and polygalacturonase activity, pectinesterase activity was present at early stages of fruit growth and increased as the fruit

grew. The greatest increase occurred during the period between the yellow stage and 50% soft stage, where the activity had about doubled, then decreased slightly as the fruit ripened further.

Coggins and Knapp (7) determined that pectinesterase of dates was not water soluble. The enzyme was strongly attached to insoluble particles, although it appeared not to be associated with tannin as a protein-tannin complex. They also showed that there was no apparent difference in pectinesterase activity among quality grades (Natural, Dry, and Waxy).

CELLULASE (E.C. 3.2.1.4)

Hasegawa and Smolensky (21) showed that cellulase activity occurred in Deglet Noor dates, and followed changes in the activity during maturation and ripening. The activity was absent at the green stage and began to develop as the fruit matured to the early red stage. The sharp increase in activity occurred during the period from the early red to the late red stage, and the activity remained fairly constant at the 50-100% soft stage.

POLYPHENOL OXIDASE (MONOPHENOL MONOOXYGENASE, E.C. 1.14.18.1)

The occurrence of polyphenol oxidase activity in the fruit has been reported (34, 35, 42). Undoubtedly, this enzyme plays an important role in the darkening of the fruit. Some of the potential substrates were discussed previously in this review, but the details are as yet unknown.

MISCELLANEOUS COMPOUNDS

Several compounds that do not fall under the above categories have been identified in dates. One unexpected compound is serotonin, which is present at the level of 8.5 ug/g date tissue (52).

Norman and Fouse (38) identified acetaldehyde as the major volatile aldehyde in dates. In studies on chemical changes during storage, they found more acetaldehyde in high quality fresh dates (Naturals) than in the No. 2 Dry dates. During a 5-month outdoor storage period, the acetaldehyde content dropped from 124 to 74 ppm on a dry weight basis. The dates also darkened considerably in this period.

Rouhani and Bassiri (44) measured chlorophyll in Iranian Shahani dates as they matured. They found a steady drop

from 420 ug/g fresh weight in dark green dates to essentially zero in ripe brown dates.

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Table 1. Composition of dates and other dried fruits per 100 grams of edible portion

	Water	Calories	Protein	Fat	Carbohydrate		Ash	Calcium	Phos- phorus	Iron	Sodium	Potas- sium	Vita- min A	Thia- mine	Ribo- flavin	Niacin	As- corbic Acid
	(g)		(g)	(g)	Total	Fiber	(g)	(mg)	(mg)	(mg)	(mg)	(mg)	(IU)	(mg)	(mg)	(mg)	(mg)
Dates	22.5	274	2.2	0.5	72.9	2.3	1.9	59	63	3.0	1	648	50	.09	.10	2.2	0
Raisins	18.0	289	2.5	0.2	77.4	0.9	1.9	62	101	3.5	27	763	20	.11	.08	0.5	1
Apricots	25.0	260	5.0	0.5	66.5	3.0	3.0	67	108	5.5	26	979	10,900	.01	.16	3.3	12
Prunes	28.0	255	2.1	0.6	67.4	1.6	1.9	51	79	3.9	8	694	1,600	.09	.17	1.6	3

From Watt, B. K., and A. L. Merrill. 1963. (56).

Table 2. Average moisture and sugar contents of dates from Saudi Arabia classified by moisture content

Variety	Moisture %	Sugars (% dry weight basis)		
		Total sugars	Reducing sugars	Sucrose
Soft (more than 30% moisture)				
Khuneizi	67.60	78.28	73.30	4.98
Hulaya	64.90	81.72	80.96	0.76
Sukkaret Yanbu	63.70	79.25	77.15	2.10
Barhee	61.40	83.19	83.19	0.00
Hilwa	61.30	83.10	77.67	5.43
Bukeira	42.30	77.08	75.24	1.84
Khalas	39.42	79.90	79.90	0.00
Semi-dry (20 to 30% moisture)				
Sifri	27.30	75.15	52.97	22.18
Khudari	25.27	72.85	54.12	18.73
Berni	25.18	76.55	46.95	29.60
Nebut Seif	24.60	78.70	45.10	23.60
Agwa	24.16	74.63	51.69	22.94
Ruzeiz	22.68	79.15	51.20	27.95
Dry (less than 20% moisture)				
Safawi	19.25	78.30	45.60	32.70
Shalabi	19.10	77.95	38.45	39.50
Sukkari	18.72	81.75	36.05	45.70
Anbara	17.95	78.80	45.20	33.60
Sakhi	16.70	79.82	39.67	40.15

From Hussein, F., S. Moustafa, F. El-Samiraea, and A. El-Zeid. 1976 (23).

Table 3. Chemical analyses of outer and inner mesocarp tissues of Natural and No. 1 Dry Deglet Noor dates (DRY WEIGHT BASIS)¹

	Natural		No. 1 Dry	
	Outer (%)	Inner (%)	Outer (%)	Inner (%)
Glucose	14.4a	13.0 b	10.7 c	7.7 d
Fructose	17.9 a	16.1 b	13.8 c	10.5 d
Sucrose	50.0 d	58.7 b	55.0 c	69.9 a
Total sugars	82.3 b	87.8 a	79.5 b	88.1 a
Alcohol soluble solids	87.1 b	91.7 a	86.7 b	91.1 a
Low methoxyl pectin	1.3 b	2.2 a	1.4 b	2.1 a
High methoxyl pectin	0.7 b	0.9 a	0.5 b	1.1 a
Protopectin	1.7 b	2.2 a	1.8 b	2.5 a
Total pectin	3.7 b	5.3 a	3.7 b	5.7 a
Lignin	0.3 a	0.1 b	0.3 a	0.1 b
Hemicellulose A ²	1.5 a	0.9 b	1.7 a	0.8 b
Hemicellulose B ³	0.8 a	0.9 a	0.8 a	1.0 a
Total Hemicellulose	2.3 a	1.7 b	2.6 a	1.8 b
Cellulose	0.8 b	1.1 a	0.9 b	1.2 a

¹Values are the average of 3 extractions. Means in the same row followed by different letters are statistically different at the 5% level.

²Extracted with dilute base.

³Extracted with concentrated base.

From Coggins, C. W., Jr., J. C. F. Knapp, and A. L. Ricker. 1968 (9).

Table 4. Amino acid content (mg/100 g dry basis) of five varieties of Iraqi dates

	Khadrawy					Sayer		Hallawy		Kustawy		Zahidi	
	Free		Total			Free	Total	Free	Total	Free	Total	Free	Total
Alanine	24 ^a	9 ^c	112 ^a	114 ^b	116 ^c	17 ^a	98 ^a	20 ^a	127 ^a	28 ^c	93 ^c	47 ^c	148 ^c
Arginine	2	2	49	56	62	3	56	2	47	5	81	5	74
Aspartic acid	7	3	156	154	160	4	148	7	156	4	162	9	130
Cystine	—	—	39	51	40	Tr.	43	Tr.	38	Tr.	58	Tr.	59
Glutamic acid	3	53	203	203	258	4	228	2	190	41	227	101	257
Glycine	7	4	112	99	113	8	114	8	118	5	120	8	118
Histidine	7	Tr.	26	27	Tr.	7	24	7	25	1	37	Tr.	27
Isoleucine	3	Tr.	49	46	61	5	51	3	52	1	62	1	48
Leucine	1	1	95	88	111	2	97	2	101	1	115	1	84
Lysine	1	3	62	58	67	2	63	3	61	7	84	10	94
Methionine	2	Tr.	13	19	23	2	15	4	22	1	16	Tr.	12
Phenylalanine	80	1	54	68	62	93	53	89	64	1	62	1	54
Proline	28	15	109	132	108	39	124	44	133	12	127	30	77
Serine	7	7	75	72	69	6	72	4	77	8	67	6	64
Threonine	3	2	58	53	55	2	56	2	62	1	63	2	46
Tryptophane	Tr.	—	51	50	—	Tr.	57	Tr.	56	—	—	—	—
Tyrosine	3	2	10	20	44	6	19	4	18	2	37	4	28
Valine	3	1	67	59	81	3	70	3	76	1	86	2	22
γ-Aminobutyric acid				84									

^aFrom Al-Rawi, N., P. Markakis, and D. H. Bauer. 1967 (2).^bFrom Sternkopf, G., and A. Main. 1973 (53).^cFrom Auda, H., H. Al-Wandawi, and L. Al-Adhami. 1976 (4).

Table 5. Fat characteristics and fatty acid composition of date pit oil

Variety	Oil content (%)	mp (C)	Iodine value	40 °D	Fatty acid composition (wt %)									
					C _{8:0}	C _{10:0}	C _{12:0}	C _{14:0}	C _{16:0}	C _{18:0}	C _{20:0}	C _{18:1}	C _{18:2}	C _{18:3}
Musafti	8.5	15.5	49.7	1.4559	0.5	0.6	20.1	12.6	11.4	0.9	0.7	45.7	6.8	0.7
Kahkaab	5.0	17.0	51.2	1.4568	0.6	0.6	22.4	12.3	10.1	1.3	0.7	44.2	7.2	0.7
Sayir	6.9	19.5	52.2	1.4573	0.7	0.5	21.5	14.6	9.9	1.2	0.8	43.5	6.6	0.7

From Mehran, M., and M. Filsoof. 1975 (36).

Table 6. Acids found in green Deglet Noor dates

	Percent of acids	
	Free Acids	Total Acids ^a
Aspartic acid	0.5%	2.9%
Cystein	0.8	0
Shikimic acid	Tr.	1.3
Quinic acid	Tr.	Tr.
Galacturonic acid	0.8	1.9
1-Malic acid	74.7	75.4
Citric acid	2.9	—
Phosphoric acid	17.0	—

^aAfter enzymatic hydrolysis.

From Maier, V. P., and A. F. Huber (unpublished data).

Table 7. Inorganic constituents of dates (mg/100 g dry weight)

Element	Halawy	Sayer
Potassium	716	657
Sodium	37	38
Calcium	65	97
Magnesium	71	79
Phosphorus	84	63
Iron	3.7	3.1
Aluminum	5.1	—
Copper	0.2	0.2
Sulfur	52	59
Manganese	3.3	4.5
Silicon	66	66
Chlorine	27	31

From Cleveland, M. M., and C. R. Fellers. 1932 (6).

Table 8. Polyphenolic constituents reported in dates

Constituents	Literature reference
Soluble proanthocyanidin tannin	30, 31, 57
Insoluble proanthocyanidin tannin	30, 31
(+) - Catechin	a
(-) - Epicatechin	a
3-O-Caffeoylshikimic acid (dactylifric acid)	29, 32
4-O-Caffeoylshikimic acid (isodactylifric acid)	29, 32
5-O-Caffeoylshikimic acid (neodactylifric acid)	29, 32
Quercetin-3-glucoside (isoquercitrin)	a
Isorhamnetin-3-glucoside ^b	a

^aMaier, V. P., and D. M. Metzler (unpublished data).

^bTentative identification

DRIP IRRIGATION OF MATURE DATE PALMS

Ed Robertson, Jr.

The Ames Group, 81-713 Highway 111, Indio, California 92201

ABSTRACT

Beginning in 1974, a small planting of abandoned 36-year-old Zahidi date palms was successfully renovated by means of good maintenance, fertilization, and irrigation with a drip system. In 1978-79, the yield averaged 220 pounds of fruit per tree.

Date Growers Inst. Rep. 54:12

This paper reports the successful renovation of a mature date planting through use of drip irrigation and good orchard maintenance. In 1974, a small abandoned date garden planted about 1938 and comprised of 43 Zahidi palms was cleaned and the palms trimmed. Before renovation began, the palms had not been pollinated, trimmed, or irrigated for several years.

The same year, a drip system of irrigation was installed in autumn. The system consists of a single one-half inch polyethylene tubing placed above ground along each side of each row. There are 4 Dripese¹ 1 GPH (gallons per hour) emitters along each side of each palm, to give a total of 8 GPH capability for each palm.

Irrigation water is from an adjacent well, the water of which does not require filtration. Water application rates range from approximately 50 gal./day/palm in the winter to about 150 to 175 gal./day/palm in the summer.

Fertilization consists of one application in May or June of approximately 8 cu. ft. of chicken manure per palm. The manure is placed equally in each of 2 furrows parallel to the tree row, about 4 or 5 feet

from the palm, and then covered with soil. The drip lines are placed on top of the covered furrow.

Production records are available for the 1978-79 crop. The 43 Zahidis averaged 220 pounds per palm, with 89% of the fruit in grade B and the balance in grade C. A similar production was realized in the previous year's crop.

The palms appear to be growing satisfactorily with this system of irrigation and fertilization and have an acceptable production, considering the previous history of abandonment and age of the palms.

¹ Mention of a trademark, proprietary product, or vendor does not constitute approval or guarantee of the product by the Date Growers' Institute.

BREEDING DATE PALMS IN CALIFORNIA

J. B. Carpenter

*Research Plant Pathologist, U. S. Department of Agriculture,
SEA-AR, U. S. Date and Citrus Station, Indio, California 92201.*

ABSTRACT

The U.S. Department of Agriculture's date breeding program began in 1948. In 1971, a substantial breeding program was undertaken with the primary objective of producing female clones with fruit suitable for mechanical harvesting and processing. About 1,800 progeny from 52 crosses were field planted. During the period 1975-1978, 710 of the female plants were evaluated for fruiting habit and fruit characters. Nine selections have been kept for either direct use or for breeding. However, none of the selections is a suitable replacement for 'Deglet Noor,' the principal California variety and one adapted to mechanical harvesting and processing. Advanced generations of backcrossed male palms have been bred for use in date breeding.

Date Growers' Inst. Rep. 54:13

The U.S. Department of Agriculture was the principal agency involved in establishing date palm (*Phoenix dactylifera* L.) culture in this country and it has fostered research on the culture, handling, and processing of dates (2, 4, 6, 9). In 1948, the Department began a date breeding program at Indio, California. Nixon (5) reviewed the early stages of that program and provided a review of previous date breeding efforts. Nixon and Furr (7) gave further information on the date breeding program, which was devoted primarily to developing backcrossed male date clones to be used ultimately in breeding superior female clones. That work and breeding of hybrid female clones continued until 1974 (8). An overview of date palm breeding was published in 1976 (3).

In 1971, Barrett (1) and colleagues made many crosses among female varieties and backcrossed male selections mostly in the third or fourth backcross generation. The primary goal in these crosses was to obtain female selections with fruit adapted to mechanical harvesting and processing and equal to or better in quality than

fruit of 'Deglet Noor,' which comprises more than 85 percent of California production. Deglet Noor is a fine semi-dry variety adapted to mechanical harvesting and processing, but it is subject to black-nose, a physiological disorder (2, 6), and it has long internodes which result in a rapid increase in height of the palms.

This paper has the dual objectives of updating information on the backcrossing of male date palms, the first aspect of breeding that was undertaken, and of reporting the results of the date breeding program of 1971 (1).

MATERIALS AND METHODS

The female date varieties used in the 1971 breeding work were commercial date varieties and lesser-known varieties with desirable characters, and one female seedling. Barrett's (1) Table 1 (Appendix 1) is reproduced for the reader's convenience. The backcrossed male palms used as pollen parents are listed in Table 1, (3, 6, 7). For convenience, backcrossed males are called "varietal males" and crosses of those males with female varieties are termed "intervarietal" crosses.

The breeding methods used have been described (1, 7). In brief, the methods provided for collection and application of uncontaminated pollen from each male clone to bagged female flowers. Appropriate safeguards against contamination with extraneous pollens were taken. Since about 1965, seedling progeny have been grown in a mixture of peat moss-coarse vermiculite in 20 x 40 cm paper fiber pots. Three to 5 seeds were planted in each pot; 1 desirable plant was selected for field planting and the others were cut off. The plants were field-planted in the pots, which were merely slashed and partially opened to permit water penetration. Palms were planted at a spacing of 6.2 x 2.0 m, basin irrigated, and fertilized as required.

Backcrossed male palms that closely resembled their female parent in vegetative characters (7) were used in breeding

further generations of backcrossed progeny.

Evaluation of female progeny has been based mostly on fruiting habit, tolerance to rain and/or high humidity, and fruit characters. To be potentially valuable, the fruit must be borne in adequate amounts on a fruit stalk long enough to permit relatively easy harvesting. The fruit itself must have adequate size, texture, color, freedom from rain and/or humidity damage, and good storage qualities. A sample rating sheet is shown (Fig. 1). A comparable sheet for evaluating and describing vegetative characters may be used in conjunction with the fruit rating.

Some progeny of the 1971 crosses began to flower in 1975 and evaluation of female palms began in the autumn of that year. By 1976 and 1977, large numbers of females flowered. Full-sized bunches and fruit may not develop until seedlings are in the third or fourth year of fruiting. However, early evaluation permitted the elimination of many inferior female progeny. This was especially true in the 1976 and 1977 seasons, when rain and humidity severely damaged the fruit of hundreds of hybrid palms even though the fruit bunches were bagged. In 1978, female palms selected in previous years were permitted to carry 4 bunches of fruit and those were handled in the same manner as commercial fruit.

RESULTS AND DISCUSSION

BACKCROSSED MALE PALMS

During the period 1965 to 1975, backcrossing was advanced one generation in 29 male lines, and 2 generations in 5 lines. Male progeny from these crosses have not been used in breeding. Based on their vegetative resemblance to the female parent, 62 male progeny were selected in 1978 from 20 of the recent backcrosses. Ten hybrid males derived from the 1971 breeding program were kept because in metaxenia tests they seemed to increase fruit size. All of these male selections

were included in the germplasm repository.

The backcrossed male palms used in the 1971 crosses and prior breeding work (1, 7) are conserved in the repository and are available to palm breeders. Pollen of several of these males has been supplied to date breeding programs in Morocco and Algeria.

FEMALE PALMS

In the 1971 breeding program, 11 female parents were crossed in various combinations with 13 backcrossed males. About 1,800 seedlings were planted. Each population originally comprised 36 plants; these were too few for genetic studies. Moreover, the palm seedlings in each pot were prejudicially thinned for good vigor before field planting. Among the palms that flowered and were examined from 1975 through 1978, 710 were females.

Table 1 provides a brief review of each cross. Most of them yielded inferior female seedlings. Rain and high humidity during the harvest season in 1976 and 1977 caused moderate-to-severe damage to fruit of many of the progeny even though the fruit bunches were covered. Many progeny were discarded before full fruiting data were obtained. Thus, in Table 1, the sums of figures under the headings for khalal color and tamar color and for texture may not add up to the number of female progeny examined.

Characters at harvest that were most deficient in discarded progeny were fruit size, tolerance to high humidity and/or rain during the khalal stage, texture, flavor, and appearance. In 1978, fruit of 22 selections was stored under refrigeration. By March 1979, 13 of the selections were discarded because of objectionable sugar crystal formation and/or collapse of soft fruit stored in thin layers 3 to 4 fruits deep.

The progeny retained included dry, semi-dry, and soft fruited selections. Some

of the soft or dry selections would probably compete successfully with currently used varieties. However, no semi-dry selection was found that could compete with the Deglet Noor variety in quality; some of the semi-dry selections might lend themselves to mechanical harvesting and processing.

After 3 years' evaluation, the 1971 breeding program yielded 9 seedlings worth saving, about one percent of the female progeny. Four useful female selections were kept from among the seven crosses based on 'Thoory' as the female parent; two female hybrids were saved from the four crosses based on 'Medjool' as the female parent; one female hybrid was kept from each of three other groups. No suitable progeny were found in 8 groups of crosses based on a single female parent. Of the 9 progeny saved, 4 had a male parent derived from 'Dayri.'

'Khadrawy' was used as a female parent and as a "varietal" male parent in the hope that this dwarfest of commercial date palms would be useful in reducing internode length in its hybrids. However, undesirable fruit characters of small size, softness, and excessive skin separation in its progeny make Khadrawy and backcrossed "Khadrawy males" poor breeding parents.

The date breeding project was concluded in 1978. The breeding and potential commercial selections are conserved in the National Date Palm Germplasm Repository at Indio, California.

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<u>Variety</u>	<u>Desirable Characters</u>
Abada	Attractiveness, glossy black fruit with frost-like bloom, midseason maturity.
Amir Hajj	High quality, little spoilage of fruit in wet weather.
Barhee	High quality, heavy yield, late maturity, low tannin in khalal stage.
Bedrayah	Large fruit, firm texture, midseason maturity.
Deglet Beida	Light-colored fruit, smooth skin, very firm texture, early maturity.
Deglet Noor	Superior quality, distinctive rich flavor, semidry texture, long fruitstalks.
Empress	High quality, attractiveness, good size, distinctive rich flavor.
Halawy	High quality, distinctive flavor, moisture tolerance, early maturity.
Horra	Good size, very firm texture, long fruitstalks, midseason maturity.
Khadrawy	High quality, dwarf stature, moisture tolerance, precocious flowering, sparse spines, early maturity.
Kush Zebda	Superior fruit quality, distinctive rich flavor, long fruitstalks.
Medjool	Large fruit, moisture tolerance, early maturity, good quality.
Tadala	Large fruit, moderate moisture tolerance, attractiveness, early maturity.
Thoory	Light-colored fruit, moderately large fruit very firm, moisture tolerance, late maturity.

[illegible]

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Table 1. Summary of female progeny derived from the 1971 date palm breeding program, including number of progeny examined, number kept, and fruit characters observed in each cross^a

Accession No 1971	Parents Female X male	Females		Khalal size		Green	Khalal color				Light brown	Tamar color			Black ^C	Soft	Texture ^d	
		Examined	Kept	Length mm.	width mm		Yellow	Red ^b	Maroon	Medium brown		Dark brown	Semi-dry	Dry				
		No.	No.	mm.	mm	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	
AMIR HAJJ																		
39	X Thoory BC ₃	18	—	37-22	53-27	1	6	5	6	—	4	6	B	3	13	—	—	
BADRAYAH																		
31	X Deglet Noor BC ₄	12	—	35-21	46-26	2	3	3	—	2	—	7	—	3	4	2	—	
32	X Halawy BC ₃	16	—	34-21	49-27	6	9	—	—	1	4	8	—	7	2	—	—	
DAYRI																		
15	X Deglet Noor BC ₄	10	—	41-21	45-22	2	5	3	—	—	3	3	—	1	3	1	—	
16	X Medjool BC ₃	17	—	40-22	51-25	—	—	5	12	—	—	—	17	6	2	3	—	
17	X Khadrawy BC ₃ , L20	17	—	33-19	55-22	6	9	1	1	2	4	8	1	8	2	—	—	
18	X Khadrawy BC ₃ , L21	5	—	41-25	49-30	1	1	2	—	—	2	3	—	4	1	—	—	
19	X Tadala BC ₁	14	—	46-23	73-26	6	8	—	—	—	—	7	2	6	2	1	—	
20	X Thoory BC ₃	7	—	42-41	50-22	1	6	2	2	2	—	1	4	—	2	3	—	
21	X (Deglet Beida X Thoory) F ₁	11	—	39-19	55-27	2	9	—	—	1	4	6	—	6	3	—	—	
DEGLET BEIDA																		
33	X Deglet Noor BC ₄	16	—	34-19	58-26	4	7	3	—	—	1	9	—	—	1	9	—	
34	X Medjool BC ₃	15	—	33-19	61-22	1	1	13 ^e	—	2	5	8	—	1	8	5	—	
35	X Dayri BC ₂	15	1	37-19	53-25	1	13	—	—	2	3	5	2	3	5	4	—	
DEGLET NODR																		
40	X Tadala BC ₁	13	—	37-17	68-26	3	2	7	1	—	2	2	1	—	4	—	—	
41	X Thoory BC ₃	9	—	33-18	55-22	1	1	4	3	—	2	—	3	—	1	2	—	
42	X Dayri BC ₂	16	—	34-19	49-19	7	5	2	2	—	5	4	2	2	4	1	—	
43	X (Deglet Beida X Thoory) F ₁	14	—	35-24	51-23	5	5	4	—	1	3	8	—	6	5	3	—	
45	X Khadrawy BC ₃ , L20	14	—	30-21	45-23	7	5	2	—	—	6	8	—	12	—	—	—	
DEGLET NODR SEEDLING																		
60	X Deglet Noor BC ₄	9	—	31-21	40-22	3	2	3	—	1	2	—	1	1	2	1	—	
61	X Khadrawy BC ₃ , L20	18	—	35-26	49-25	—	9	6	1	5	4	5	3	14	2	—	—	
62	X Dayri BC ₂	13	—	31-28	42-21	5	6	1	1	—	4	—	1	4	2	1	—	
63	X Tadala BC ₁	17	—	43-19	55-23	4	2	9	—	2	5	6	—	5	2	6	—	
EMPRESS																		
46	X Deglet Noor BC ₄	12	—	36-23	48-27	2	6	3	1	—	5	3	1	5	5	—	—	
47	X Medjool BC ₃	16	—	38-24	55-30	3	3	9 ^e	1	2	3	8	2	8	4	1	—	
48	X Khadrawy BC ₃ , L20	16	—	34-22	49-29	2	13	—	—	1	7	8	—	14	2	—	—	
49	X Khadrawy BC ₃ , L21	20	1	38-28	56-30	7	13	—	—	—	5	14	—	12	7	—	—	
50	X Tadala BC ₁	15	—	36-21	54-27	7	8	—	—	2	8	2	—	3	6	2	—	
51	X Dayri BC ₂	16	—	36-23	51-24	5	11	—	—	2	3	8	—	3	6	4	—	
52	X (Dayri X Deglet Noor) F ₁	19	—	41-29	55-33	—	11	8	—	4	2	3	—	2	3	1	—	
HORRA																		
37	X Tadala BC ₁	18	—	33-19	56-28	8	10	—	—	2	6	8	—	3	8	2	—	
38	X Dayri BC ₂	6	1	36-21	51-22	—	6	—	—	1	3	2	—	—	5	1	—	
KHADRAWY																		
27	X Tadala BC ₁	14	—	41-22	53-24	4	10	—	—	—	3	10	—	9	4	—	—	
28	X Thoory BC ₃	17	—	38-22	49-21	4	4	8	—	1	8	5	2	12	4	—	—	
29	X Dayri BC ₂	14	—	34-18	47-33	10	3	—	—	—	5	8	1	12	2	—	—	
KUSH ZEBDA																		
53	X Deglet Noor BC ₄ f	6	—	39-25	52-29	3	2	1	—	1	1	2	—	—	3	—	—	
54	X Khadrawy BC ₃ , L20 f	6	—	32-22	44-31	1	5	—	—	—	5	1	—	6	—	—	—	
55	X Thoory BC ₃	10	—	42-22	56-29	1	3	5	—	1	2	6	—	8	1	—	—	
56	X Dayri BC ₂	12	—	37-32	49-26	3	6	—	—	1	—	3	—	—	2	—	—	
57	X (Deglet Beida X Thoory) F ₁	14	—	36-25	46-26	5	9	—	—	—	4	8	—	8	4	—	—	
58	X (Dayri X Deglet Noor) F ₁	14	—	38-25	52-25	3	6	5	—	—	3	3	—	3	2	1	—	
59	X Tadala BC ₁	13	—	38-21	51-27	11	2	—	—	1	—	9	—	8	1	—	—	
MEDJOL																		
22	X Tadala BC ₁	14	1	47-25	64-33	5	3	4	—	1	5	5	3	10	3	—	—	
23	X Thoory BC ₃	11	—	41-25	58-28	—	4	6	1	1	2	4	2	3	3	4	—	
24	X Dayri BC ₂	14	—	32-20	50-28	1	8	3	1	—	2	2	4	4	3	4	—	
25	X (Dayri X Deglet Noor) F ₁	13	1	36-27	68-40	—	7	3	3	—	2	4	5	4	5	—	—	
THODRY																		
8	X Deglet Noor BC ₄	14	1	34-20	48-24	4	6	2	—	5	6	1	—	—	5	7	—	
9	X Medjool BC ₃	13	—	37-23	48-27	—	1	11	1	—	8	4	1	3	2	8	—	
10	X Khadrawy BC ₃ , L20	14	—	33-21	43-25	—	14	—	—	2	7	5	—	13	1	—	—	
11	X Khadrawy BC ₃ , L21	16	1	30-27	48-27	2	14	—	—	1	7	8	—	7	7	1	—	
12	X Halawy BC ₃	16	1	38-24	58-29	7	7	—	—	1	4	7	—	6	5	—	—	
13	X Tadala BC ₁	18	—	39-18	61-27	11	6	1	—	1	7	8	—	3	9	5	—	
14	X (Dayri X Deglet Noor) F ₁	14	1	37-21	50-30	3	5	4	1	2	6	4	1	—	2	10	—	

^a Notes on the table: The total number of female palms examined included all palms within a cross that fruited from 1975-1978. The total shown is sometimes greater than the number of observations under another heading, e.g. Khalal color, because complete information was not available on each lot of fruit harvested. Rain damage in 1976 and 1977 complicated harvesting.

^b Includes red stripe or blush over yellow.

^c Blackish brown or purple.

^d Examples of texture in the tamar stage: soft, Barhee; semidry, Deglet Noor; dry, Thoory.

^e Nearly all red blush or stripe over yellow.

^f Not fruited in 1978.

OCCURRENCE OF *FUSARIUM OXYSPORUM* AND *GLIOCLADIUM VERMOESENII* ON *PHOENIX CANARIENSIS* IN CALIFORNIA, AND THEIR EFFECTS ON SEEDLINGS OF *PHOENIX* SPECIES

Tolbert V. Feather, Howard D. Ohr, and Donald E. Munnecke

Research Assistant, Extension Plant Pathologist, and Professor of Plant Pathology and
Plant Pathologist, respectively, Department of Plant Pathology,
University of California, Riverside, California 92521.

ABSTRACT

A severe disease has been found on Canary Island palm (*Phoenix canariensis*) in the coastal areas of southern California. *Fusarium oxysporum* Schlecht. and *Gliocladium vermoeseni* (Biourge) Thom., have been isolated from diseased trees. These fungi are pathogenic singly and in combination on 4- to 6-month old seedlings of Canary Island palm and date palm (*Phoenix dactylifera*), 'Deglet Noor.' The occurrence of *F. oxysporum* on *P. canariensis* is significant to the date industry of southern California since this fungus might be established in the date-growing area and become pathogenic on date palms.

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Canary Island palm (*Phoenix canariensis* Hort. ex Chabaud) is used extensively in California as an ornamental. A disease of these palms in California was reported in 1938 (2) as a bud rot caused by the fungus *Gliocladium vermoeseni* (Biourge) Thom. (= *Penicillium vermoeseni*). Other fungi were not associated with this disease and it was of minor importance on *P. canariensis*, but was considered a major problem on some other ornamental palm species. The disease on *P. canariensis* was characterized by a discoloration of the leaf rachis followed by death of the pinnae on one or both sides of the rachis. A dark punky rot was present in the rachis tissue and blister-like pustules of pink colored spores formed on dead leaves. The oldest leaves died first, then progressively younger leaves died and the terminal bud was invaded, resulting in death of the palm.

The occurrence of *Fusarium oxysporum* on *P. canariensis* in California is

significant because the bayoud disease, incited by *F. oxysporum* Schlecht. f. sp. *albedinis* (Kill. & Maire) Malencon, is the most important disease of date palm (*Phoenix dactylifera* L.). The pathogen is found on date palms in Algeria and Morocco (3). In 1973 Corte (4) reported the occurrence of a bayoud-like disease on *P. canariensis* in Italy caused by *F. oxysporum* f. sp. *albedinis*. In the same year Mercier and Louvet (5) found *F. oxysporum* on diseased *P. canariensis* in southern France. In pathogenicity tests they found that date palm seedlings were attacked more severely than *P. canariensis* seedlings, and that the fungus appeared identical to *F. oxysporum* f. sp. *albedinis*. A *Fusarium* disease of Canary Island palm was also reported in 1977 in Japan by Arai and Yamamoto (1). Symptoms appeared to be similar to bayoud symptoms on date palm and the *F. oxysporum* isolate was pathogenic on *P. canariensis* and *P. dactylifera*. The symptoms of the three reported *Fusarium* diseases of Canary Island palm are: one-sided death of leaves, presence of brown and/or red vascular bundles in the leaf rachis and trunk, and brown, rotted areas in the leaf rachis tissue. Affected trees die when the terminal bud is invaded.

What appears to be a combination of the diseases caused by *F. oxysporum* and *G. vermoeseni* has been found on mature *P. canariensis* palms in southern California. The disease is characterized by the reduction of the live canopy as leaves die, until only young leaves remain intact (Fig. 1, 2). New leaves are not produced and the terminal bud is eventually invaded and killed. An affected tree may collapse within several months, or the

tree may survive for several years.

Symptoms first appear on mature or recently matured leaves. Typically, spines or pinnae on one side of the leaf base become brown and dry, and pinnae on one side of the rachis progressively die from the base towards the tip of the leaf. Pinnae on the other side of the leaf then die from the tip to the base. Occasionally pinnae on both sides of the rachis die from the tip to the base. Before individual pinnae die, dark or necrotic streaks may be observed along the lengths of the pinnae. As the leaf dies, a brown discoloration appears on the lower side of the rachis and may extend the length and width of the rachis. Pink spore masses of *G. vermoeseni* may be seen in blisters under the brown epidermis of the affected leaf, or on old leaf bases on the tree.

A black-brown dry rot, adjacent to the outer discoloration, may be found upon dissection of the leaf rachis. When the rachis is sectioned longitudinally, discolored vascular bundles and discolored tissues adjacent to the bundles are visible as thin brown streaks. Frequently, a brilliant pink-purple discoloration is present within the leaf rachis. Both *G. vermoeseni* and *F. oxysporum* may be isolated, either in combination or in pure cultures, from any of the affected areas of the rachis. However, pure cultures of *F. oxysporum* are usually isolated from the discolored vascular bundles, and pure cultures of *G. vermoeseni* are usually isolated from the black-brown dry rot areas.

Preliminary tests show that *G. vermoeseni* and *F. oxysporum* are pathogenic singly and in combination on 4-6 month old seedlings of *P. canariensis* and date palm 'Deglet Noor.' *F. oxysporum* causes

a wilt with vascular discoloration if spores of the fungus are applied in a stem puncture or if spore suspensions are poured into pots as a root drench. *G. vermoeseni* causes a rot of affected seedling tissues and is apparently only pathogenic if spores are applied in a stem puncture. In combination, the two fungi cause either a wilt or general rot of the seedlings. Work is in progress to determine the relationship and relative importance of the two fungi in the disease complex on *P. canariensis*.

Currently, the disease has been found only on *P. canariensis* in Los Angeles, Orange, San Bernardino, and San Diego counties and only on the west side of the mountains that separate the desert from the coastal plain. In areas where the disease is present, significant losses of trees have occurred in the past 3 years. Field observations of disease spread and past cultural histories of different plantings suggest that the disease is spread by pruning.

G. vermoeseni has been known to cause disease among palms along the

California coast for 40 years, but is of no importance on *P. dactylifera*. The purpose of this report is to notify the date industry of California that a *Fusarium* disease of *P. canariensis* does exist in California. We do not know if this disease will become established among date palms in California. To avoid possible disease spread, *P. canariensis* palms should not be moved from the coast to desert areas, and any equipment used on coastal palms should be thoroughly disinfested before being used in commercial date plantings.

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Figure 1. Healthy *Phoenix canariensis* with a complete canopy.



Figure 2. Diseased *Phoenix canariensis* with a reduced canopy. Dead leaves remain attached at the base of intact young leaves.

PLANTLET PRODUCTION IN VITRO FROM PHOENIX DACTYLIFERA L.

Brent Tisserat, G. Foster and D. DeMason

*Research Geneticist and Agricultural Research Technician, respectively,
U. S. Department of Agriculture, SEA-AR, U. S. Date and Citrus Station,
Indio, California 92201;*

*Assistant Professor of Botany, Botany and Plant Sciences,
University of California, Riverside, California 92521.*

ABSTRACT

Tissue cultures of *Phoenix dactylifera* showed callus growth, embryogenesis or adventitious root initiation. Callus obtained from tissues that included inflorescences, lateral buds, shoot tips, meristele, and embryos initiated plantlets. Plantlets were produced in a sequence of events that resembled the zygotic embryogenesis and germination processes. Isolated lateral buds and shoot tips rooted and produced clonal plantlets.

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Date palm (*Phoenix dactylifera* L.) cultivars may at this time be propagated only by offshoots. Offshoots are axillary buds which develop from the base of leaves usually during the juvenile phase of growth, the offshoots may be successfully transplanted. Only a limited number of offshoots are produced in the lifetime of a date palm. Introduction of new cultivars or increasing the existing date acreage with clonal varieties would be slow if limited to propagation by offshoots.

Plant tissue culture was employed to find a new method of clonal propagation for the date palm. Tissues of date palms cultured by earlier investigators showed some organogenetic potential (1, 2, 3, 4, 5). We report the formation of embryoids and rooted lateral buds from clonal and from zygotic tissues.

MATERIALS AND METHODS

Lateral buds, shoot tips, inflorescence

¹ Mention of a trademark, proprietary product or vendor does not constitute approval or guarantee of the product by the U.S. Department of Agriculture, and does not imply its approval to the exclusion of other products that may also be suitable.

and meristele tissue explants were obtained from offshoots of 5-year-old seedling palms grown at Indio, California. Clonal explants were excised and transferred to anti-oxidant solutions of 150 mg/l citric acid and 100 mg/l ascorbic acid. Excised date embryos were obtained from mature seeds of 'Halawy' fruit. Explants were surface sterilized by soaking 15 min. in 5:1 Clorox bleach solution (1 drop Tween-20 emulsifier per 100 ml solution) and rinsed 3 times with sterile distilled water. An anvil hand cutter was used to open seeds and exposed embryos were removed with a scalpel. Explants and embryos were planted on a modified Murashige and Skoog medium containing Murashige and Skoog inorganic salts, 3% sucrose, 0.4 mg/l thiamine-HCl, 40 mg/l adenine sulfate, 100 mg/l inositol, 0.8% phytagar, 0.3% activated charcoal, 3 mg/l N⁶ (Δ^2 -isopentyl)-adenine (2ip) and 0, 1.0, 10 and 100 mg/l 2, 4-dichlorophenoxy-acetic acid (2, 4-D) or α -naphthelene acetic acid (NAA). Cultures were incubated at 25° C under a 16-hr photoperiod of 300 lux for 8 wk. In some cases lateral buds and shoot tip cultures were transferred to a 16-hr photoperiod of 10,000 lux to enhance leaf differentiation. Data recording and reculturing to fresh media was conducted every 8 wk. Plant tissue at various stages of callus and embryoid development were fixed in FAA solution of 90 ml 50% ethyl alcohol, 5 ml glacial acetic acid and 5 ml formalin solution. Materials were embedded in paraffin, sectioned at 8 μ , and stained with safranin and fast green.

RESULTS AND DISCUSSION

Regeneration of plantlets from buds and tips.

On nutrient medium containing low levels of auxins such as 0.0 and 1 mg/l

NAA or 2, 4-D, shoot development from buds and tips occurred (Figs. 1 and 2). Within the first weeks of culture the buds and shoot tip explants turned green, initiated leaves, and enlarged considerably in size. Following several recultures to fresh medium, rooting occurred in some cultures (Fig. 3). Root initiation was infrequent and did not appear to be related to the nutrient medium composition. Lateral buds without prior leaf differentiation failed to survive in any cultures employed.

Examination of dissected offshoots containing 20-40 leaves revealed that only a limited number of living lateral buds may be obtained (Table 1). For a single offshoot, only 2 or 3 buds with early leaf development occurred. The type and number of lateral buds and appendages was not influenced by the sex of the offshoot.

Initiation of plantlets from callus

Good callus growth occurred from explants cultured on medium containing 10 and 100 mg/l 2,4-D and NAA (Fig. 4). Buds and shoot tips initiated yellow-white nodular callus (Table 2). Histological examination of these nodules revealed them to be precursors to asexual embryos (Fig. 5). This callus was subculturable to medium containing 10 mg/l 2,4-D. Transfer to medium devoid of auxin allowed further embryoid development and subsequent germination (Figs. 6 and 7).

Plantlets were also obtained from callus derived from meristele, excised embryos, and flower buds. Embryos cultured on high levels of auxins, (10 and 100 mg/l), produced nodular callus from which asexual embryoids arose. Embryos cultured on lower auxin concentrations germinated normally. Floral bud reproductive tissues, especially male anthers, usually turned brown and died after a few

weeks in culture. Vestigial female carpels on surviving male flowers enlarged and became quite prominent (Fig. 8). Friable callus usually initiated from the floral bud strand. In some cases roots and embryoids were initiated from this callus. Meristeme explants enlarged initially during culture and produced a nodular callus from which plantlets subsequently arose.

The developmental pattern of these asexual embryos corresponded to the zygotic situation (Figs. 6 and 7). Initially a white cotyledon-like structure initiated from the nodular callus. This cotyledon-like structure was found to be the haustorial end of the cotyledon, and the embryonic shoot and root tip were embedded within the callus. In the early embryoid development, the cotyledonary haustorium and sheath were easily identified. Eventually this embryoid structure became detached from the callus and grew independently. During the following weeks the sheath elongated several centimeters,

and eventually the plumule and the radicle broke through the sheath (Fig. 7).

Tomlinson (6) described 2 distinct phases of palm seed germination. In the first the embryo is extruded from the seed enclosed within the sheath and in the second the plumule and radicle emerge from the sheathing organ and become visible externally. Both conditions were recapitulated in embryoids derived asexually from date palms. Transfers of asexual plantlets to free-living conditions are in progress. Plantlets were obtained from both clonal and embryo explants. Production of plantlets from clonal callus offers a means to clone superior date genotypes on an accelerated scale.

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Table 1. Incidence of culturable buds (> 3 mm in length) and appendages from offshoots of date palm varieties and hybrids^a

Variety	BUDS/OFFSHOOT					
	Total	Decomposed buds	Vegetative appendages	Reproductive appendages	Buds with leaves	Buds without leaves
Barhee	11.6	2.8	1	0.2	2.6	5
Deglet Noor	14.2	4.2	1	2.8	2.6	3.6
Empress seedlings ^b						14
Male	20.4	2.4	1.3	1.5	1.2	11.4
Female	20.0	2.6	1.3	2.2	2.6	4.6
Halawy	11.6	3.4	1.4	1.6	0.6	3.8
Khadrawy	14	3.4	3.2	1.8	1.8	5.5
Medjool	15.6	3	2.6	1.8	2.7	7.6
Thoory	10.6	7.8	1.4	0.8	2	3.2
Zahidi	12	4.8	1	2.2	0.8	

^a Offshoots were obtained from 7-year-old clonal palms; weight of offshoots varied from 8-23 lbs. Five offshoots were used to represent each variety.

^b Offshoots were obtained from 7-year-old seedling date palms in which Empress is the female parent; six female trees with 19 offshoots and five male trees with 22 offshoots were used.

Table 2. Influence of growth regulators on lateral buds and shoot tips from date palm seedling offshoots

Plant growth regulator in medium (mg/l)		Weight of culture/treatment (mg)	% callus/treatment	Tip and bud Length/treatment (cm)
2,4-D	0.0	4.00 ± 0.95	0	1.3 ± 0.7
	0.1	2.50 ± 0.12	40	1.4 ± 0.3
	1.0	1.36 ± 0.14	60	1.9 ± 1.0
	10.0	0.92 ± 0.76	70	1.2 ± 0.2
	100.0	0.32 ± 0.11	80	1.0 ± 0.4
NAA	0.1	1.88 ± 0.82	20	1.5 ± 0.3
	1.0	1.35 ± 0.37	20	1.2 ± 0.1
	10.0	1.48 ± 0.97	30	1.2 ± 0.1
	100.0	0.54 ± 0.21	50	1.0 ± 0.1

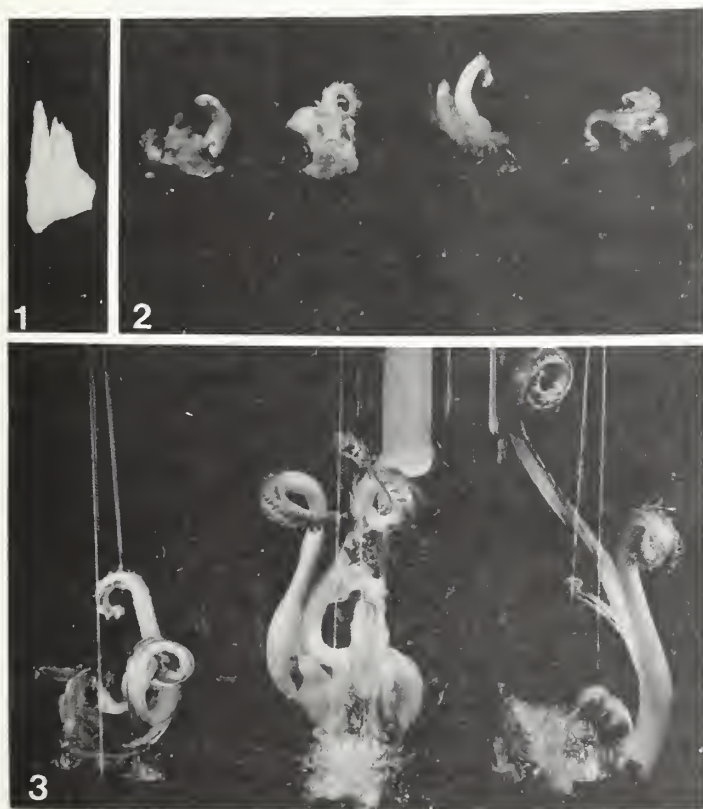


Figure 1. Freshly excised shoot tip explant ready to be planted on nutrient medium (about 2X).

Figure 2. Shoot tip explants after 16 wk in culture when leaves have enlarged and turned green (about 1X).

Figure 3. Shoot tip explants after 3 mo in culture when additional leaves have been initiated (about 1X).

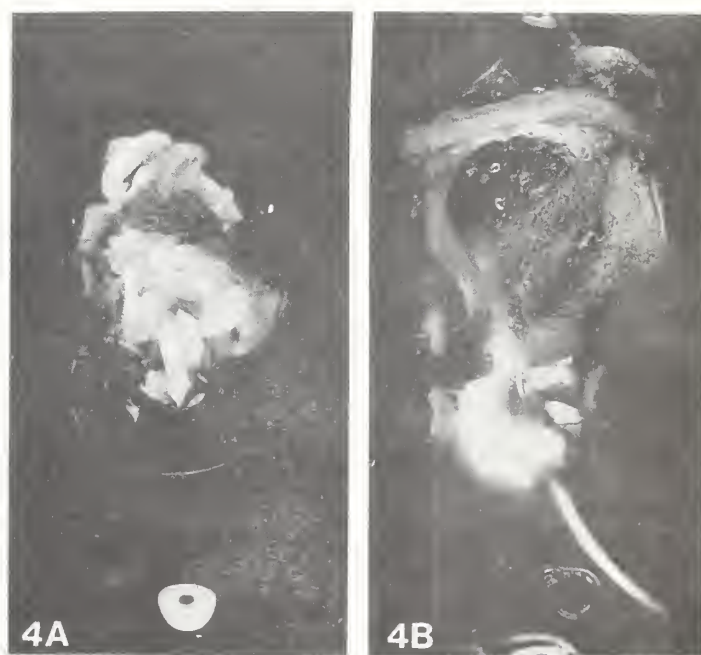


Figure 4. Shoot tip cultures with initiation of roots from the basal region on nutrient medium devoid of hormones (about 2X).

(A) Early root initiation stage (10 wk old).
(B) Mature rooted offshoot (20 wk old).

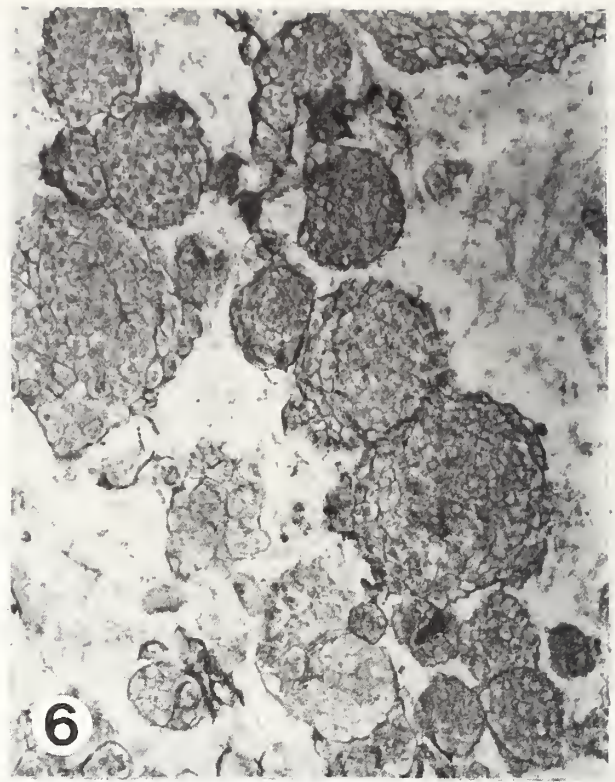


Figure 5. Initiation of callus from lateral bud tissue on nutrient medium containing 10 mg/l 2,4-D and 3 mg/l 2ip (about 1X).

Figure 6. Transverse section of nodular callus showing early embryoid development. Nodules are precursors to asexual embryoids and show definite organization (about 25X).

Figure 7. Late development of asexual embryo. Note that embryoid root end is embedded within the callus mass while the haustorial end is growing out (about 25X).

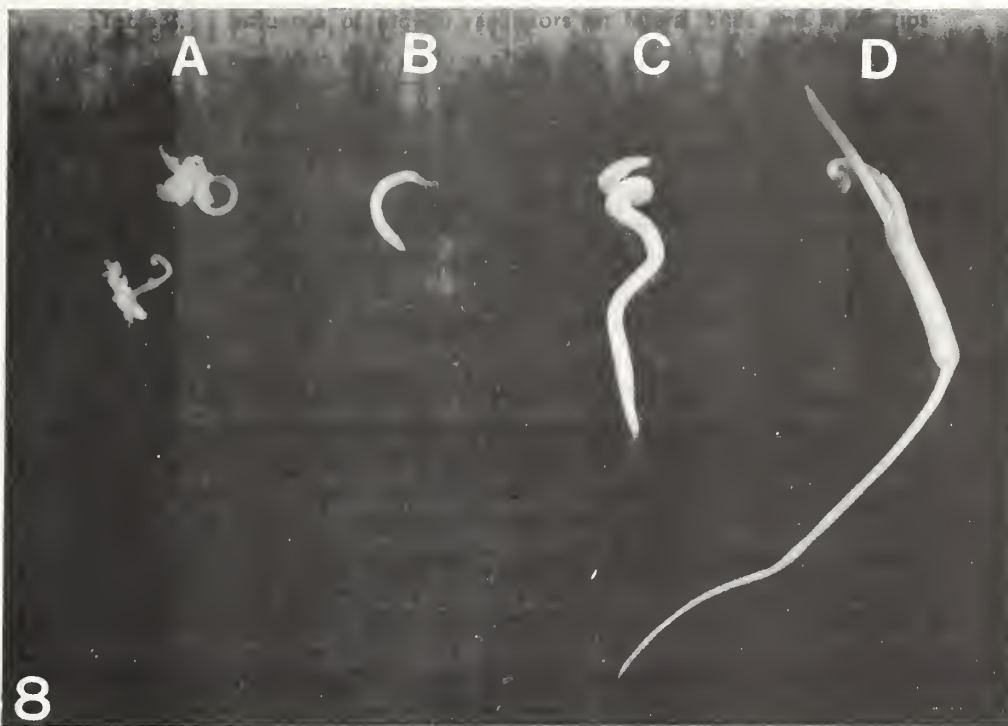


Figure 8. Developmental pattern of asexual embryogenesis from date palm callus tissue (about 1 X).

- (A) Initiation of embryos, early embryo state.
- (B) Elongation of embryo.
- (C) Initiation of slit-shaped opening.
- (D) Germination of embryo emergence of plumule and root through the cotyledonary sheath.



Figure 9. Formation of carpels from male flower buds after 8 wk in culture (about 5 X).

ISOZYMES AS GENETIC INDICATORS IN DATE PALMS

Brent Tisserat and Andrew M. Torres

*Research Geneticist, U. S. Department of Agriculture, SEA-AR,
U. S. Date and Citrus Station, Indio, California 92201;*

*Professor of Botany, Department of Botany,
University of Kansas, Lawrence, Kansas 66045*

ABSTRACT

Several gene-enzyme systems of date palm (*Phoenix dactylifera*) leaflets were examined by starch gel electrophoresis and were found to be polymorphic. Seedling populations and their parents from the U.S. Department of Agriculture date breeding project provided genotype material. The genetic control of isozymes of alcohol dehydrogenase, esterase, glutamate oxaloacetate transaminase, phosphoglucose isomerase and phosphoglucose mutase were examined. These isozymes were coded by 7 genes with 14 alleles. Forty-five female and 20 male date palm cultivars were genotyped to provide single-gene markers for the date palm. Possible applications are discussed.

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Enzyme polymorphism or isozymes have been found in a wide variety of organisms (3, 6, 7). Isozymes are multiple molecular forms of an enzyme with similar or identical catalytic activities in a single organism (6). Isozymes have differing primary structures because they are encoded in different genes, either allelic or non-allelic. These isozymes may be further modified by conjugation of molecules with reactive groups. Isozyme markers have been used in biochemistry, taxonomic, genetic and evolutionary, and developmental biology studies (6). Isozymes are usually unaffected by the environment, collinear with the gene, and are nearly direct gene products.

The heterozygosity and perennial nature of the date palm have prevented much advancement of its genetics (1). The objective of the USDA date breeding program, begun in 1948, was to develop superior male and female cultivars (cvs). Male date palms that approached genetically the female cv were sought by repeated backcrossing of male progeny with vegetative characters similar to those

of the female parent to the female cv (2, 5). Backcrossed male selections of a particular cv were crossed with different cvs to make intervarietal crossings which might combine the desirable traits of 2 or more cvs (1). Males used in intervarietal crossings had been backcrossed at least 3 or more generations. The formal genetics of date palms were determined by using isozymes of several enzyme systems from the parents and progeny of the USDA breeding program. Isozymes have provided reliable and easily obtained single-gene markers in other perennials (9, 10). Genotypes of various male and female date palm cvs and their relatives were surveyed to provide an initial biochemical profile.

MATERIALS AND METHODS

Plant samples were obtained at the U.S. Date and Citrus Station, Indio, and Laflin Date Gardens, Thermal, California (Table 1). Female cvs are distinguished from backcrossed females and males by the absence of the BC (backcrossed) and breeding line (L) designations accompanying the latter's name. A one cm² piece of a healthy leaflet from fully expanded 3- to 5-year-old mature leaves was placed in 2.3 cm² plastic weighing boats. The leaflet tissue was macerated by a 454 gm hammer with 3 to 4 drops of crushing buffer, and the resultant solution was filtered onto 5 x 7 mm Whatman # 1 $\frac{1}{2}$ / filter paper or Beckman electrophoresis paper. The crushing buffer consisted of 0.01 M pH 7.5 tris-citrate with 0.1 M 2-mercapthanol, 12% soluble polyvinylpyrrolidone (MW 40,000) and 1 mM ethylenediaminetetraacetic acid, and 3% bovine serum albumin.

The general methods used for starch gel electrophoresis have been described (8). The gel tris-citrate buffer for alcohol dehydrogenase (ADH), glutamate oxaloa-

cetate transaminase (GOT) and phosphoglucose isomerase (PGI) was pH 7.9, 0.019 M and it was pH 8.0, 0.016 M for esterase (EST) and phosphoglucose mutase (PGM). The electrode buffer was 0.04 M pH 8.7 sodium borate. Staining mixtures for ADH, GOT, PGI and PGM were given by Torres *et al.* (10). The mixture for EST consisted of 400 mg/fast blue RR salt, 30 ml 1 M tris-citrate buffer pH 7.0, 220 ml H₂O, 4 ml 1% α -naphthyl acetate and 4 ml 1% α -naphthyl butyrate. Gel slices stained for PGI and PGM were fixed in 50% aqueous ethanol, the others in 50% aqueous methanol. All observed isozymes were found in the anodal section of the gel.

Genes are named after the enzyme system they specify. When 2 genes code for the same enzyme, the locus that specifies the isozyme's slower set in relation to the anode is called the 1; the faster is 2. For example, the gene Got-1 specifies the slower migrating set of GOT isozymes. The allele which codes for the slower migrating isozyme within a set is called S; the faster is F (e.g. Got-1^F).

RESULTS

A biochemical profile was compiled for date palm cvs occurring in the Coachella Valley (Table 1). As shown in this table, much variation existed between the cvs for these 7 gene-enzyme systems. Analysis of the enzyme systems of 15 replicates of 'Medjool' and 'Deglet Noor' revealed genetic uniformity. Also, analysis of isozymes from various mature leaves of a single Medjool specimen revealed similar uniformity for the 7 enzyme systems.

¹Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products that may also be suitable.

The results of the genetic studies are summarized in Tables 2 and 3. Ten F_1 progeny populations derived from 5 female and 3 male cvs which resulted in 26 crossing combinations were available for analysis, several in replicate. Representative zymograms for various cv enzyme systems are illustrated (Fig. 1).

The patterns of isozymes (zymograms) produced by ADH consisted of 1 or 3 bands depending on the cv. Alcohol dehydrogenase is a 2 subunit (dimeric) enzyme; the homozygous condition is represented by a single-band, F/F , and the heterozygous condition, by a 3-banded pattern, F/S . Only 2 phenotypes were available for observation of segregation ratios out of the 6 possible crossing combinations ($F/F \times F/F$ and $F/F \times F/S$). The ADH results did not deviate from the expected results based on the χ^2 tests. For example, among the 20 F_1 seedlings from the cross of 'Dayri' (F/F) $\times$ Khadrawy L21 BC₃ (F/S), 8 were F/S and 12 were F/F ($\chi^2 = .8$, $P > .30$ for goodness of fit to the expected 1:1 ratio, (Table 2). In one case, a specimen of *P. sylvestris* (L.) Roxb. had an ADH isozyme which migrated faster than F and was consequently labeled G (Table 1).

Esterases were specified by 2 genes, $Est-1$ and $Est-2$, and occurred in 2 regions (Fig. 1). Although variation in the $Est-1$ region occurred, no segregation analyses were available other than $S/S \times S/S$; 73 F_1 's of 6 crosses were S/S . Based on the cvs in Table 1, it appears that the molecule is monomeric and the gene has 2 alleles, F and S . The homozygous condition is represented by a single-band, F/F or S/S ; the heterozygous condition, by a 2-banded pattern, F/S . Variation in $Est-2$ could be described by the presence or absence of an isozyme due to a null or silent allele. The homozygous null genotype (N/N) is represented by a missing isozyme, the heterozygous (A/N) by a fine band, and the normal dark band (A/N) represents the homozygous condition. The observed segregation ratios agreed with results predicted by a null hypothesis. Polymorphic isozymes of GOT were found in 2 separate regions, $Got-1$ and $Got-2$. One to 3 isozymes represented $Got-1$; the enzyme system was dimeric and specified by 2 alleles, F and S . The GOT-2 zymograms consist of 1 or 2 iso-

zymes, suggesting a monomeric enzyme specified by 2 alleles, F and S . In one case a single F_1 , *P. humilis* Royle, was found to have a third allele of $Got-2$, R (retarded), whose isozyme migrated slower than S .

Zymograms of PGI consisted of enzyme bands in 2 regions, although only $Pgi-1$ showed any isozyme variation near the origin. The $Pgi-1$ isozymes numbers 1 to 3 suggested a dimeric relationship specified by a gene, $Pgi-1$, with 2 alleles, F and S .

Zymograms of PGM appear to be a monomer coded by a single gene, Pgm , consisting of 2 alleles, F and S . The results of both $Pgi-1$ and Pgm progeny segregation ratios were found to be predictable (Table 2).

DISCUSSION

The segregation ratios from these 7 enzyme systems, based on parents and progeny, followed a predictable Mendelian inheritance.

The genetic uniformity found for specimens of Deglet Noor and Medjool was expected because of their asexual propagation through offshoots. Therefore, all cvs derived from offshoots should consistently show their distinct enzyme system patterns when compared to other cvs listed in Table 1. Various applications of isozymes as genetic markers can be utilized. Isozyme patterns, for example, can be used to detect unintended pollinations among progeny of attempted hybridizations. For example, if a supposed offspring of Dayri (F/F) $\times$ Khadrawy (F/S) L21 BC₃ was S/S for ADH (Table 1), it would indicate that Dayri could not be the female parent because Dayri has no S allele. In such cases, seeds were mixed or mislabeled during harvesting or storage. Zymograms of date palms may also be used as additional confirmation tests to identify an offshoot's parentage. Analyses of leaflet tissue from offshoots for just the 7 enzyme systems surveyed could determine if an offshoot was actually from a particular cv.

An isozyme test is comparable to a blood test and can be used to determine whether an F_1 seedling or an offshoot could be the progeny of $A \times B$ cv or a particular cv. Isozymes may be used as genetic indicators, but isozyme zymograms cannot be used as a positive

identification of parental source. Identification of parents can be made with a high degree of confidence if sufficient parental markers are known. These isozymes or genetic indicators may assist in the solution of problems with nomenclature. For example, the same cv has been given names in various date-growing regions (4). Isozymes analysis along with present taxonomic procedures could help to alleviate such confusion. Backcrossed males may be selected for genetic resemblance to the cv by both vegetative characteristics and isozyme composition. Comparisons of samples from tissue cultured plantlets with samples from the tree of origin may provide a measure of the genetic uniformity preserved through tissue culture propagation.

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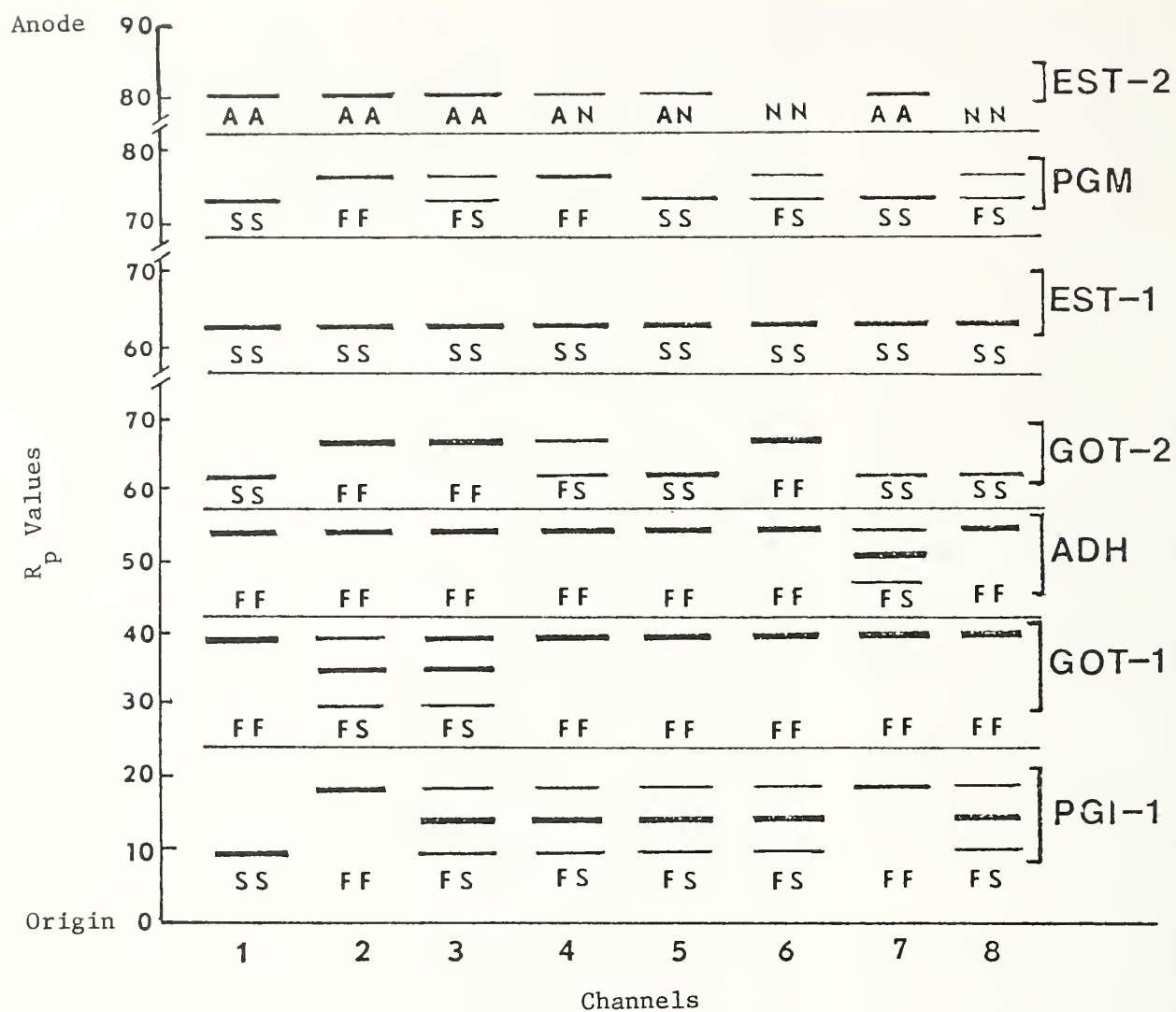


Figure 1. Schematic illustrations of zymograms of selected date palm cultivars. Enzyme systems indicated at right, R_f values at left. Genotypes are below each zymogram. Origin at 0, anode at top. Channel 1, 'Barhee'; 2, Dayri; 3, Deglet Noor; 4, 'Empress'; 5, 'Khadrawy'; 6, Medjool; 7, Khadrawy L21, BC3; 8, Tadala BC1. The first six are females; the last two, males.

Table 1. Varieties and selections field location at the U. S. Date and Citrus Station, (block-row-tree) or Laffin's Date Garden (L.D.G.), and genotypes of date palms and relatives found in the Coachella Valley

Variety or selection	Field Location	Genotypes						
		Adh	Est-1	Est-2	Got-1	Got-2	Pgi-1	Pgm
Female:								
Abada	11-2-7	FF	SS	AN	FF	FS	FS	SS
Amir Hajj	12-18-3	FF	SS	NN	FS	FS	FF	SS
Ashrasi	12-18-5	FF	SS	AA	FF	FS	FS	SS
Badrayah	12-19-2	FF	FF	AA	FS	FF	FS	SS
Barhee	12-18-6	FF	SS	AA	FF	SS	SS	SS
Bentamoda	12-19-4	FF	SS	AN	FS	FS	FF	SS
Dayri	12-19-16	FF	SS	AA	FS	FF	FF	FF
Deglet Beida	12-31-3	FF	SS	NN	FS	FS	FS	SS
Deglet Noor	12-30-3	FF	SS	AA	FS	FF	FS	FS
Deglet Noor L10 BC ₃	12-31-2	FF	SS	AA	FF	FF	FS	FS
Empress	12-18-2	FF	SS	AN	FF	FS	FS	FF
Halawy	12-20-5	FF	SS	AN	FF	SS	FS	SS
Hayany	L.D.G.	FF	FF	NN	FF	SS	FF	SS
Haziz	12-20-6	FF	SS	AA	FF	FS	FS	FS
Hilali	12-21-3	FF	SS	AN	FF	SS	FF	FS
Honey	L.D.G.	FS	FF	AA	FF	FS	FF	FS
Horra	11-3-3	FF	FF	AA	FS	FF	FS	SS
Iteema	L.D.G.	FF	FF	NN	SS	FF	FF	FF
Kahsba	L.D.G.	FF	FF	NN	FF	SS	FF	FS
Khadrawy	12-20-2	FF	SS	AN	FF	SS	FS	SS
Khalasa	12-21-4	FF	SS	AA	FS	SS	FF	SS
Khir	12-21-5	FF	SS	AA	FF	SS	FF	FS
Kush Zebda	12-21-1	FF	SS	AN	FS	SS	FF	SS
Kustawy	L.D.G.	FF	FF	AN	FF	SS	FF	FS
Maktoom	L.D.G.	FF	FF	NN	FF	SS	FF	SS
Medjool	7-2-2	FF	SS	NN	FF	FF	FS	FS
Medjool L30 BC ₃	12-31-1	FF	SS	NN	FF	FF	FS	SS
Menakher	11-5-8	FF	FF	AN	FF	FF	FS	SS
Peggy Ann	12-21-6	FF	SS	NN	FF	FS	SS	FS
<u>Phoenix abyssinica Drude</u>	12-23-6	FF	FS	AA	FF	SS	FF	FS
Rhars	L.D.G.	FF	FF	NN	FF	SS	FS	FS
Saidy	L.D.G.	FS	FF	AN	FF	SS	FF	SS
Sayer	12-22-5	FF	FF	NN	FF	SS	FS	SS
Tazizoot	L.D.G.	FF	FF	NN	FF	SS	FF	SS
Thoory	12-22-2	FF	SS	NN	FF	FS	FS	FS
Zahidi	12-23-1	FF	SS	NN	FS	FS	FF	SS
Male:								
Barhee L6 BC ₄	12-30-2	FF	SS	AA	FF	SS	FS	FS
Boyer	12-17-2	FF	SS	AA	FF	FS	FF	SS
Crane	12-17-3	FF	SS	AA	FS	FF	FF	FS
Dayri L7 BC ₂	12-20-1	FF	SS	AA	FF	SS	FS	SS
Dayri L7 BC ₃	12-29-6	FS	SS	AA	FS	FF	FF	FS
Dayri F ₁	12-29-1	FF	SS	AA	SS	FS	FF	FS
Deglet Beida F ₁	12-29-4	FF	SS	AN	FF	FS	FS	FS
Deglet Noor L10 BC ₄	11-51-9	FF	SS	AA	FS	FF	FF	FS
Deglet Noor L10 BC ₅	11-40-6	FF	SS	AA	FF	SS	FS	SS
Fard # 4	12-17-4	FF	SS	AN	FS	SS	FS	FS
Halawy L14 BC ₃	11-53-1	FF	SS	NN	FF	SS	FS	SS
Hilali L17 BC ₃	12-30-5	FF	SS	AN	FF	SS	FF	FS?
Jarvis	12-17-5	FF	SS	NN	FF	FF	FF	SS
Khadrawy L21 BC ₃	12-29-3	FS	SS	AA	FF	SS	FF	SS
Khalasa L22 BC ₂	12-31-6	FF	SS	AA	FF	SS	FF	SS
Khir L23 BC ₂	12-30-4	FF	SS	AA	FF	SS	FF	SS
Medjool L30 BC ₃	12-30-1	FF	SS	AA	SS	FF	FF	SS
Medjool L33 BC ₂	11-58-5	FF	SS	NN	FF	FF	FF	FF
<i>P. humilis</i> Royle F ₁	11-50-4	FF	FF	AN	FF	SR ^a	SS	RS ^b
<i>P. sylvestris</i> (L.) Roxb.	12-23-2	GG	FS	AA	SS	SS	FF	SS
Tadala L1 BC ₁	11-30-6	FF	SS	NN	FF	SS	FS	FS
Thoory L42 BC ₃	12-29-2	FF	SS	NN	FF	FS	SS	FF

^a 3 banded GOT-2 with the slowest band below S.

^b The slower R PGM band migrates to a position below S of other date cvs.

Table 2. Genotypes of parents and progeny

Parents and Progeny	Genotypes					
	Adh	Est-2	Got-1	Got-2	Pgi-1	Pgm
Dayri x Khadrawy L21 BC ₃ = F ₁	FF FS 8 FS 12 FF	AA AA 13 AA	FS FF 17 FS 7 FF	FF SS 23 FS	FF FF 20 FF	FF SS 13 FS
Dayri x Thoory L42 BC ₃ = F ₁	FF FF 7 FF	AA NN 8 AN	FS FF 5 FS 3	FF FS 3 FS 5 FF	FF SS 8 FS	FF FF 8 FF
Deglet Noor x Tadala L1 BC ₁ = F ₁	FF FF ---	AA NN 21 AN	FS FF ---	FF SS ---	FS FS ---	FS FS 7 SS 12 FS
Deglet Noor x Thoory L42 BC ₃ = F ₁	FF FF 4 FF	AA NN ---	FS FF ---	FF FS 2 FS 2 FF	FS SS 2 SS 2 FS	FS FF 2 FS 2 FF
Empress x Khadrawy L21 BC ₃ = F ₁	FF FS 5 FS 9 FF	AN AA 5 AN 9 AA	FF FF 12 FF	FS FS 6 FS 8 SS	FS FF 8 FS 6 FF	FF SS 12 FS
Empress x Tadala L1 BC ₁ = F ₁	FF FF 14 FF	AN NN 8 AN 6 NN	FF FF ---	FS SS 5 SS 8 FS	FS FS 2 SS 6 FS 6 FF	FF FS 4 FS 5 FF
Khadrawy x Tadala L1 BC ₁ = F ₁	FF FF ---	AN NN 11 AN 3 NN	FF FF 14 FF	SS SS 14 SS	FS FS ---	SS FS 6 SS 7 FS
Khadrawy x Thoory L42 BC ₃ = F ₁	FF FF 11 FF	AN NN 5 AN 6 NN	FF FF 11 FF	SS FS ---	FS SS 4 SS 7 FS	SS FF ---
Thoory x Tadala L1 BC ₁ = F ₁	FF FF 40 FF	NN NN 8 NN	FF FF ---	FS SS 8 SS 6 FS	FS FS 8 SS 22 FS 10 FF	FS FS 3 SS 7 FS 2 FF

Table 3. Genes, alleles, and crossing combinations analyzed in date palm cvs

Gene/Enzyme	Alleles	No. of parental genotypes observed ♀ (♂)	F ₁ populations available for segregation analyses	No. of crosses analyzed
Adh	F, S	1 (2)	2	2
Est-1	F, S	1 (1)	1	1
Est-2	A, N	3 (2)	5	5
Got-1	F, S	2 (1)	2	2
Got-2	F, S	3 (2)	5	4
Pgi-1	F, S	2 (3)	5	5
Pgm	F, S	3 (3)	6	4
Totals	14	15 (14)	26	23

THE NATIONAL DATE PALM GERMPLASM REPOSITORY

J. B. Carpenter

*Research Plant Pathologist, U. S. Department of Agriculture,
SEA-AR, U. S. Date and Citrus Station, Indio, California 92201.*

ABSTRACT

A National Date Palm Germplasm Repository was established at Indio, California in 1977 by the U.S. Department of Agriculture. The repository comprises important Old World and domestic varieties of dates, new hybrid female selections, advanced backcrossed male palm selections, and a few Phoenix species.

Date Growers' Inst. Rep. 54:29

The National Date Palm Germplasm Repository was established in 1977 as a part of the United States Department of Agriculture's germplasm conservation program, which is now under the direction of the Science and Education Administration, Agricultural Research.

SEA-AR and its antecedent organizations began to introduce Old World date palm varieties into the United States in the late 1800's. From 1901 to 1929 several important introductions of large numbers of date varieties and offshoots were made (4, 5, 7). In 1904, a date research station was established by the Department at Mecca, California. The Station was re-established at Indio in 1907.

The collection of Old World (6) and local date varieties (Nixon, R. W. 1955. Date varieties of American origin. Unpublished ms.) grew to large proportions during the ensuing years. In 1971, the decision was made to retain in the collection (Table 1) only those female varieties which were considered useful commercially or which had some valuable characteristics for breeding new varieties, (1, 2, 3).

Before 1954, several seedling male palms of local origin were acquired because each had one or more useful characters — abundant pollen production, time of flowering, metaxenic effect on fruit. Of these males, five have been conserved (Table 2).

A date breeding program was started at Indio in 1948. The work on that program is summarized elsewhere in this report (2). The first objective was to breed backcrossed male palms that might approach the female parent in genetic composition. The backcrossed male palms derived from that program are listed in Tables 3 and 4.

The female hybrids retained from the substantial intervarietal breeding project undertaken in 1971 by Barrett (1) are listed in Table 5.

Phoenix species in the repository include, in addition to P. dactylifera L., P. acaulis (?) Buch. —Ham. ex Roxb., P. humilis Royle, P. reclinata Jacq., and P. sylvestris (L.) Roxb.

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Table 1. Female date palm varieties, USDA/SEA-AR germplasm repository

Accession number	Name	Accession number	Name
<u>Old World varieties^a</u>			
78 - 12	Amir Hajj	78 - 17	Horra
78 - 14	Ashrasi	78 - 21	Khadrawy
78 - 18	Badrayah	78 - 27	Khalasa
78 - 15	Barhee	78 - 28	Khir
78 - 19	Bentamoda	78 - 25	Kush Zebda
78 - 20	Dayri	78 - 43	Medjool
78 - 16	Deglet Beida	78 - 41	Menakher
78 - 22	Deglet Noor	78 - 31	Sayer
78 - 23	Halawy	78 - 29	Thoory
78 - 26	Hilali	78 - 32	Zahidi
<u>American varieties</u>			
78 - 13	Abbada		
78 - 24	Haziz		
78 - 30	Peggy Ann		

^a See Literature Cited (6).

Table 3. Male date palms used in 1971 crosses, USDA/SEA-AR germplasm repository

Accession number	Breeding line	Name
<u>Backcrossed males</u> <u>listed by recurrent</u> <u>female parent</u>		
56-128-1		Tadala BC ₁
60-271-2	L 7	Dayri BC ₂
60-276-5	L 30	Medjool BC ₃
62-430-4	L 21	Khadrawy BC ₃
62-431-3	L 42	Thoory BC ₃
63-394-21	L 20	Khadrawy BC ₃
64-351-1	L 14	Halawy BC ₃
64-351-18	L 14	Halawy BC ₃
64-354-22	L 10	Deglet Noor BC ₄
<u>F₁ males</u>		
61-408-3		(Deglet Beida X Thoory No. 20) F ₁
61-408-5		Same cross.
61-414-6		(Dayri X Deglet Noor BC ₃) F ₁

Table 2. Superior male date palms of local origin, USDA/SEA-AR germplasm repository^a

Accession number	Name
78 - 7	Barhee A 19
78 - 8	Boyer No. 11
78 - 9	Crane
78 - 10	Fard No. 4
78 - 11	Jarvis No. 1

^a Acquired locally before 1954.

Table 4. Backcrossed male date palms not yet used in breeding, USDA/SEA-AR germplasm repository

Accession number	Number of progeny kept	Breeding line	Name
<u>Backcrossed males, listed by recurrent female parent</u>			
60-270	1	L 6	Barhee BC ₃
64-354	1	L 10	Deglet Noor BC ₄
69-154	1	L 21	Khadrawy BC ₄
63-394	1	L 20	Khadrawy BC ₃
66-11	3	L 11	Amir Hajj BC ₂
66-12	3	L 5	Barhee BC ₃
66-13	1	L 34	Menakher BC ₂
66-14	3	L 43	Zahidi BC ₂
66-15	3	L 44	Zahidi BC ₂
66-16	3	L 49	Barhee BC ₂
69-150	4	L 10	Deglet Noor BC ₅
69-151	3	L 13	Halawy BC ₃
69-152	3	L 14	Halawy BC ₄
69-155	2	L 22	Khalasa BC ₂
69-156	3	L 31	Medjool BC ₄
69-157	3	L 33	Medjool BC ₃
69-158	3	L 41	Tazizoot BC ₃
70-31	3	L 30	Medjool BC ₄
70-39	4	L 7	Dayri BC ₃
70-41	4	L 6	Barhee BC ₄
70-43	3	L 42	Thoory BC ₄
<u>F₁ males</u>			
69-190	3		(Deglet Noor seedling X Deglet Noor BC ₄) F ₁
70-42	3		[Deglet Beida X (Deglet Beida X Thoory No. 20)] F ₁

Table 5. Hybrid female date palms, USDA/SEA-AR germplasm repository

Accession number	Hybrid (Female X male)
69-155-14	Khalasa X Khalasa BC ₂
71-8-1	Thoory X Deglet Noor BC ₄
71-11-21	Thoory X Khadrawy BC ₃
71-12-33	Thoory X Halawy BC ₃
71-14-1	Thoory X (Dayri X Deglet Noor) F ₁
71-22-4	Medjool X Tadala BC ₁
71-25-15	Medjool X (Dayri X Deglet Noor) F ₁
71-25-36	Same.
71-35-4	Deglet Beida X Dayri BC ₂
71-38-10	Horra X Dayri BC ₂
71-49-5	Empress X Khadrawy BC ₃

MEMBERSHIP ROLL: 1979

FRIENDS

Cal-Date Company, Div. Tenneco West, Inc.
P.O. Drawer HHH Indio 92202

Desert Packing Company
P.O. Box 1210 Indio 92202

Foster-Gardner, Inc.
1577 First Street Coachella 92236

Hadley Date Gardens
83-555 Airport Blvd. Thermal 92274

Security Pacific National Bank
P.O. Drawer JJJ Indio 92202

COMPANY MEMBERS

Alamo Ranch Company (John Keck)
P.O. Drawer FF Indio 92202

Blumberg Ranch (Lewis Blumberg)
37-593 Thompson Road Rancho Mirage 92270

California Date Administrative Committee
(Arne Ezell)
81-855 Hwy. 111, Room 2-G Indio 92201

Codekas Bros.
56-220 Jackson Thermal 92274

Cottonwood Acres
P.O. Box 816 Thermal 92274

Covalda Date Company (Lee Anderson)
P.O. Box 908 Coachella 92236

De Bonne Ranch Management
P.O. Box 1935 Palm Desert 92260

Desert Date Ranches
P.O. Box 1804 Indio 92202

HMS Agricultural Corp.
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Library Serials Unit
California State Polytechnic University
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Palm Tree Company
Drawer E Indio 92202

Ranchers Labor Pool, Inc.
P.O. Box 833 Indio 92202

Shields Date Gardens
80-225 Hwy. 111 Indio 92201

Sun Date, Inc.
85-215 Ave. 50 Coachella 92236

INDIVIDUAL MEMBERS

Beckstrom, Lloyd
5435 S. Mavis Whittier 90601

Bell, Lindy E.
14159 Dickens, # 109 Sherman Oaks 91403

Brown Date Garden (T. R. Brown)
69-667 Polk St. Thermal 92274

Carpenter, J. B.
44-455 Clinton St. Indio 92201

Cavanaugh, H. L.
76-353 Hwy. 111 Indian Wells 92260

Cowan, Connie
P.O. Box 833 Indio 92202

Dharmasakti, P.
1037 Michai Road Nongkhai, Thailand

Dondero, Peter P.
81-931 Victoria Indio 92201

Eltaher, Farouk H.
Pomology Dept., Plant Science Bldg.
Cornell University Ithaca, N.Y. 14853

Ensley, Harold D.
P.O. Drawer 1787 Indio 92202

Erickson, Leif
Box 1763 Indio 92202

Fish, Ted
69-245 Polk St. Thermal 92274

Fruit and Food Technology Research Inst.
Private Bag Stellenbosch, C.P., South Africa

¹ All addresses California unless otherwise specified

Government of Western Australia
 Librarian, Dept. of Agriculture
 Jarrah Road South Perth 6151,
 Western Australia, Australia

Hooten, John
 73-941 Hwy. 111 Palm Desert 92260

Hopkinson, John N.
 220 E. Ross Rd. El Centro 92243

Hrabetin, Frank G.
 2141 Ocean Blvd. Newport Beach 92661

Khalaf, Hadi A.
 P.O. Box 12347
 University of Florida . . . Gainesville, FL 32604

Kitagawa and Sons, Inc.
 77-950 Fillmore Thermal, 92274

Kuklinski, Paul S.
 39 White Oak Road . . . Wellesley, MA 02181

Leach, George
 89-200 Ave. 81 Thermal 92274

Loud, A. R.
 P.O. Box 2039 Pomona 91766

McLeod, Rose L.
 P.O. Box 31 Colville, WA 99114

Mitchell, David H.
 P.O. Box 833 Indio 92202

Mitchell, Donald H.
 P.O. Box 833 Indio 92202

Nordland, Olaf
 81-487 Alberta Ave. Indio 92201

Ottman, Clarence
 72-654 Thrush Road, No. 1 . . . Palm Desert 92260

Pareck, O.P.
 c/o Director, Central Arid Zone
 Research Inst. Jodhpur, Rajasthan, India

Patterson, K. K.
 81-370 Date Palm Ave. Indio 92201

Pennsylvania State University
 (Pattee Library) . . . University Park, PA 16802

Rapkin, Joseph E.
 777 E. Wisconsin Ave. . . . Milwaukee, WI 53202

Schmid, Walter R.
 7931 Lampson Ave. . . . Garden Grove 92641

Sica, Morris G.
 1750 Larkspur Drive Placentia 92670

Swingle, Leonhardt
 44-566 Swingle Ave. Indio 92201

Swingle, Mrs. W. T.
 3400 Laguna St., No. 309 . . . San Francisco 94123

Wood, Neil, Mr. and Mrs.
 8121 Dacosta Street Downey 90240



